5-7-2011

Frequency of Injuries with Periodized Resistance Training in Young Untrained Men and Women

Sarah A. Neuschwander
University of Connecticut - Storrs, sarahneuschwander33@gmail.com

Frequency of Injuries with Periodized Resistance Training in Young Untrained Men and Women

Sarah Neuschwander

B.S., University of Connecticut, 2009

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Masters of Arts

at the

University of Connecticut

2011

APPROVAL PAGE

Master of Arts Thesis

Frequency of Injuries with Periodized Resistance Training in Young Untrained Men and Women

Presented by

Sarah Ann Neuschwander, B.S.

Major Advisor ______________________________

William J. Kraemer, Ph.D.

Associate Advisor ______________________________

Carl M. Maresh, Ph.D.

Associate Advisor ______________________________

Lindsay J. DiStefano, Ph.D.

University of Connecticut

2011

Acknowledgements

To Dr. William J. Kraemer, my major advisor: You have blessed me with such a great opportunity by allowing me to be a part of your team here at the University of Connecticut. I appreciate everything you have done for me and the experience and knowledge that you have passed on to me in my time here. You and your family are special people and your kindness will not be forgotten, however far away I may end up. I sincerely appreciate you, and what you have contributed to this field of study. Thank you.

To Dr. Carl M. Maresh, and Dr. Lindsay DiStefano, my advisory committee: Dr. Maresh, thank you for accepting me into this prestigious program that you have worked so hard to build; I am eternally grateful for the knowledge I have gained in my time here and the caliber of professionals I am able to exist among. Thank you for being a part of my committee, your input is highly regarded. Dr. DiStefano, thank you for setting aside time for me out of your busy schedule. I know how busy you are and your help was tremendous. You are a great inspiration as a young successful female in this competitive field. Thank you for being a part of my committee.

To Brittany Volk, Courtenay D. Lewis, and Brett A. Comstock, my colleagues: I could not have done it without your patience, guidance, and support. Thank you for your dedication to this program as well as the success of all who are involved. I wish you all the best of luck in your future careers, and hope to continue our friendships for years to come.

To HPL colleagues: Thank you for a great experience, I wish you all the best of luck with your future.

To my parents and close friends: Mom and dad thank you for all your love and support throughout the years. You have helped shape me into the person I am today and continue to help me grow and succeed. You have afforded me every opportunity; none of this would be possible without you. I love you. To all of my close friends who have supported me and believed in me, thank you. Your love has given me confidence to persevere.

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Abstract

64 men and women completed a 32 week periodized training program designed to improve lean body mass, muscle size and strength. 37 men, average age 23.6 years (SD ±3.2), height 176.68 cm (SD±6.2), weight 78.9 kg (SD±15.1) and 27 women, average age 22.7 years (SD ±3.4), height 163.9 cm (SD±6.7) weight 64.8 kg (SD±12.4) resistance trained 3 times a week with NSCA certified strength and conditioning specialist, performing a series of planned total body workouts. Injuries were documented in the subjects personalized workout log by the trainers. The injury definition included any complaint of perceived pain in which the subject adjusted the load or sets/reps, ceased the exercise, or discontinued the training session. This research yielded an injury rate of (10.7 injuries per 1,000 exposure hours). Injury rates by exercise revealed squat (4.9 injuries/1,000 exposure hours), hamstring machine (5.0 injuries/1,000 exposure hours), and push press (4.5 injuries/1,000 exposure hours) were the highest values among exercises. The body part most injured was the shoulder (12.01 injuries/1,000 exposure hours). A gender comparison observed a significant difference in injury between men and women (χ^2= 7.49, V=0.3) A comparison of injury rates by repetition range (Strength, Hypertrophy, Endurance) observed Strength to be significantly different from

Hypertrophy (χ^2=5.39, V=0.3) and Endurance (χ^2=7.5, V=0.3) workouts. A comparison of repetition ranges from the first half of the research to the second half revealed that although Strength was significantly different from Hypertrophy and Endurance within Month 1-4 (Strength versus Hypertrophy, χ^2= 11.28, V=0.4)(Strength versus Endurance, χ^2=25.6, V=0.6), there was no significant difference among any repetition range in Month 5-8. Hypertrophy and Endurance were significantly different from Month 1-4 to Month 5-8 (Hypertrophy 1-4 versus Hypertrophy 5-8, χ^2=5.94, V=0.3)(Endurance 1-4 versus Endurance 5-8, χ^2=16, V=0.5)

Chapter One

Introduction

Physical fitness is fundamental in the maintenance of health; more recently resistance training and all of its sub-units have become a preferred mode of exercise due to its profound health benefits.[1, 2] Where there is movement, there is potential for injury. Injury spans all aspects of exercise from the weekend warrior to the elite athlete.

Extensive research has been done on injury in sport; [3-14] however there is much less on resistance training and injury.[15-21] As the popularity of resistance training continues to grow, it is important to identify risk factors and injury rates to aid in the successful implementation of safe resistance training as a mode of exercise. The literature is limited in its research of resistance training and injury rates. There is no consistency across the studies that have been done; the injury definitions and the reported units of exposure for injury pose the greatest problem when attempting to make comparisons across studies. This research will use an injury definition that does not depend on the time lost by the athlete; and the injury rates will be reported per 1,000 exposure hours allowing them to be interpreted in an absolute manner.

We examined any acute injury, where the injury occurred, what exercise was being done when the injury occurred, and what intensity was being used. The operational definition of injury was any complaint of perceived pain in which the subject adjusted the load or sets/reps, ceased the exercise, or discontinued the training session.

Statement of the Problem

The purpose of this research was to examine the frequency of perceived injury with a 32 week periodized resistance training program in young untrained men and women

Chapter Two

Review of Literature

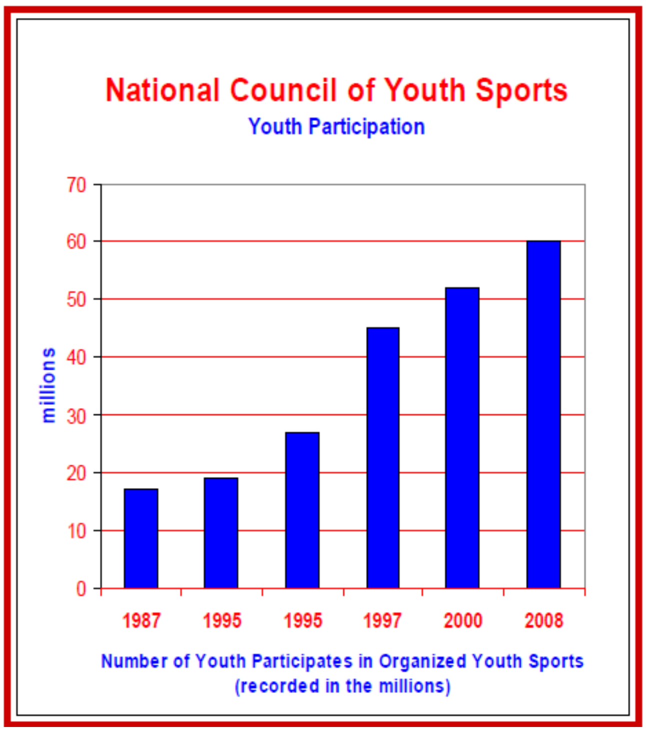
Physical Activity

Physical Activity is a staple in the lives of Americans; the Center for Disease Control felt it necessary to publish the health benefits as well as the daily recommendations. Physical activity aids in the weight management and increases strength of muscle and bone. It decreases the risk of Cardiovascular Disease, Type II Diabetes, Metabolic Syndrome, and some cancers. Physical activity improves the quality of life and longevity of life through increased mental health and mood as well as an increased life expectancy. The Center for Disease Control recommends that youth are physically active sixty minutes per day and on three days a week perform some kind of strengthening training. Adults are recommended to be physically active for one hundred and fifty minutes per week and on two of those days perform some type of strengthening training.[1]

Sport Participation

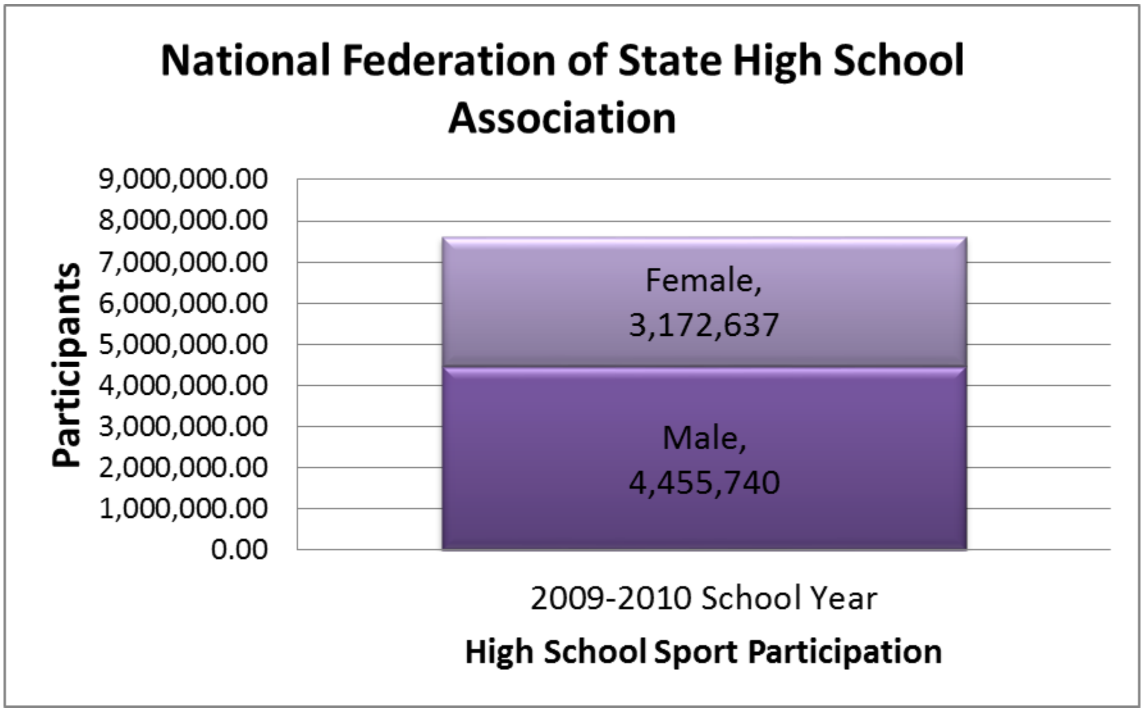
The National Council of Youth Sports surveyed all of the major youth sport organizations in the nation with a questionnaire inquiring about their participation rates. The National Council of Youth Sports has completed this survey since 1987, but the most recent was 2008 when they found that there were sixty million American youth participating in organized sport.[22] Adirim et al concluded that youth sport participation provided benefits such as, increased fitness, increased motor coordination and improved socialization skills. [15]

Figure 2.1



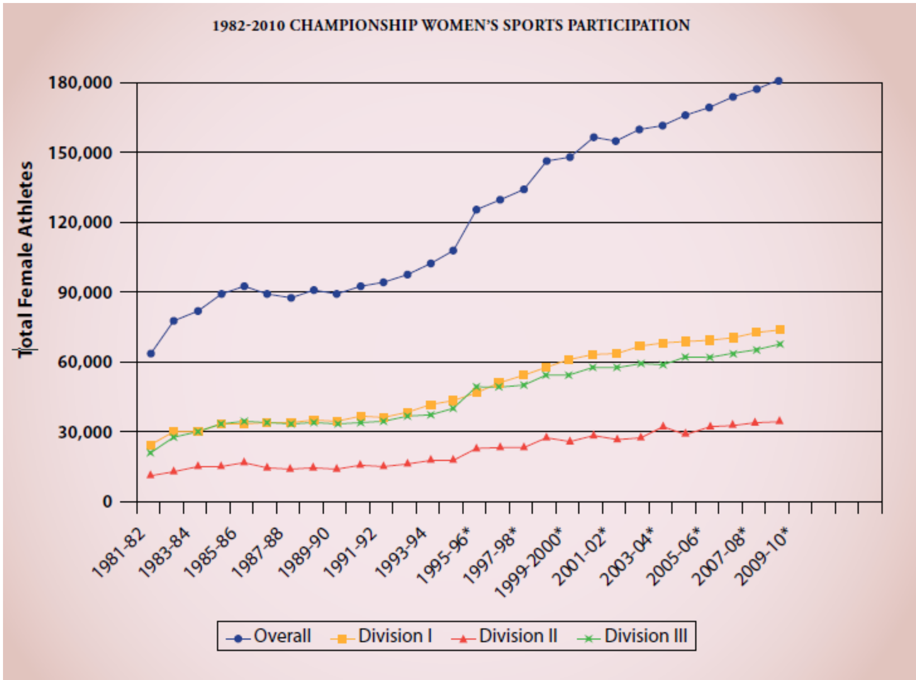
The National Federation of High School Associations conducted a survey of high school participation in sport; they included all fifty states as well as the District of Columbia. The National Federation of High School Association found that in the 2009-2010 school year, there were 7,628,377 participants. 4,455,740 participants were male and 3,172,637 participants were female.[23]

Figure 2.2



The National Collegiate Athletic Association's Sports Sponsorship an Participation Rates Report tracks participation rates of its athletes every year since 1981. The participation rate of student athletes in the 2009-2010 school year was 430,301 participants in championship level sport. Of those, 182,426 were female athletes and 245,875 were male athletes.[24]

Figure 2.3



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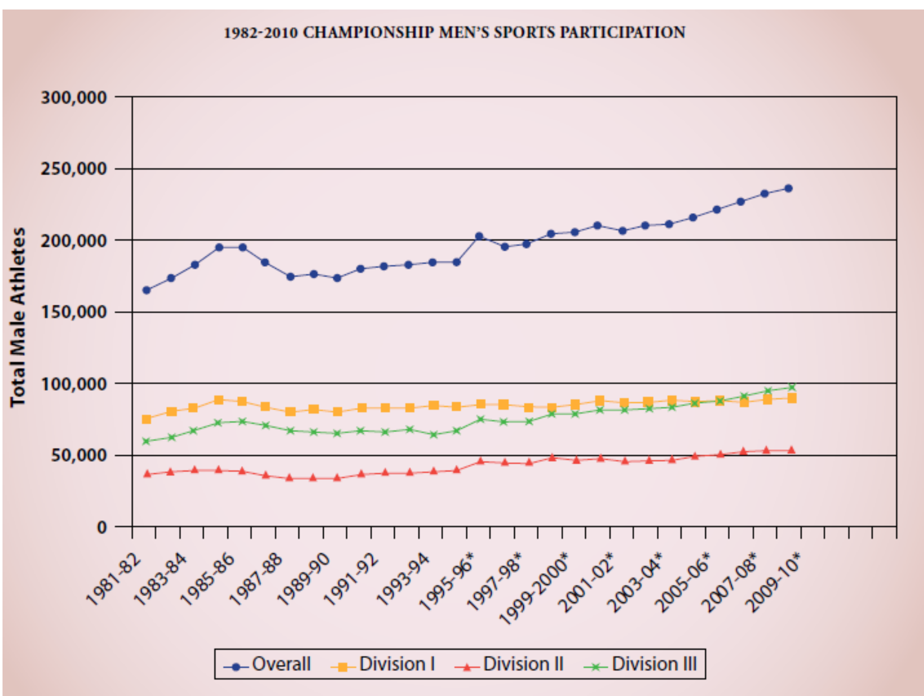


Injury in Sport

Caine et al found in a review of 49 studies on youth sport injuries that girls had a higher injury rate than boys in Cross-country running, Gymnastics and Soccer. There was conflicting evidence between boys and girls Basketball. Caine found that gender differences were particularly evident when comparing injury rates for specific locations, such as girls having a higher incidence rate of knee injuries. This difference was attributed to possible hormonal differences, increased joint laxity in female athletes, anatomical differences, and differences in motor control of knee function predisposing them to injury in cutting and jumping sports. Nearly half of all the injuries seen in youth were of the overuse nature.[7]

Knowles et al researched high school athletes in North Caroline and found that there were 10,531 injuries per year. Sport played, incidence of prior injury and gender were significant predictors of injury rates.[12] McGuine et al found in a review of high school athlete injuries, that with the exception of the knee, injury rates break even between male and female athletes. This is mostly attributed to the inconsistent style of injury documentation; it makes the formation of meaningful comparisons nearly impossible. [13] Baynnon et al found that ankle sprains were one of the most common injuries among high school and college sport athletes and that men had an injury rate of .68 injuries per 1,000 person days of exposure to sport and women had an injury rate of .97 injuries per 1,000 person days of exposure to sport.[4]

Boles et al reviewed the female athlete and found that certain isolated injury patterns may observe a slight increase of injury in men over women, but when discussing overall injury, women are at a greater risk for injury when compared to men. Clark et al found similar result in an earlier study of the same nature. [5, 8] Hootman et al did a review in which he looked at NCAA injuries from 1988-2004 and found that gender was a significant risk factor in injury rates. 54% of all the injuries were sustained to the lower body. Of the four highest injury rates , women held three of the places; the other being football which isn't comparable to any women's sport. The three highest women's sports injury rates were comparable to male sports; gymnastics, holding the highest injury rate with .33 injuries per 1,000 athlete exposures, basketball, and soccer. Women also had a higher rate of concussions when compared to men; women's ice hockey had a .91 injuries per 1,000 athlete exposures.[10] The research on lower body injuries, specifically anterior cruciate ligament injuries has consistently reveled women to have higher injury rates.[3, 10, 14] Boling et al found with research of college age physically active people that patellofemoral pain syndrome is one of the most common lower extremity conditions reported; affecting 1:4 people. Female sex was one of the two significant risk factors for developing patellofemoral pain syndrome.[6] Jones et al studied military population and found risk factors of injury were; high volumes of running, how levels of physical activity, high and low levels of flexibility, sedentary lifestyle, and tobacco use. [11] Deitch et al compared NBA and WNBA injury rates and found that women had a higher incidence of lower extremity injury that translated into an extremely significant difference (χ^2=9.625, $P < .01$). WNBA observed 14.6 injuries per 1,000 athlete exposures where the NBA observed (11.6 injuries per 1,000 athlete exposures. [9]

Resistance Training

Resistance training is the use of an external load on the body to stimulate muscle with the intent to train and develop that muscle.[2, 25-27]

Ratamuss et al and Kraemer et al updated the American College of Sports Medicine's position stand on resistance exercise. Finding observed benefits of resistance exercise to include improvement of cardiovascular function, a decrease in coronary heart disease and Type II Diabetes, prevention of osteoporosis, improvement in dynamic stability an preservation of functional capacity, promotion of weight loss and weight maintenance, and finally that it fosters psychological well-being. The trainable characteristics of resistance training include muscular strength, power, hypertrophy, and local muscular endurance. Characteristics that are enhanced by resistance training include speed/agility, balance, coordination, jumping ability, and flexibility. The frequency recommendations for resistance training are divided into novice, intermediate and advanced. Novice should resistance train two to three days per week with total body emphasis. Intermediate level will train between three and four days per week, and advanced resistance training consists of four to six days per week. [28, 29]

Styles of Resistance Training

General resistance training increases strength and muscle mass for fitness and is a mechanism for sport performance improvement and decrease I of injury in sport[30] Boling et al investigated the patellofemoral pain syndrome and found support for strengthening of quadriceps and hamstring musculature along with teaching the proper technique for performing dynamic tasks (decreased hip internal rotation angle, increase knee flexion) as components of effective injury prevention program geared toward patellofemoral pain syndrome.[6] McGuine et al suggested an intervention in which strength is improved in the lower extremity, agility and biomechanics training to decrese the lower extremity injury rates in high school athletes. [13]

Bodybuilding is a style of resistance training designed to increase muscle size, symmetry and muscle definition. It is a non-ballistic form of training where the individual moves the weight very slowly in an effort to increase time under tension for the result desired. It is important to note the significant nutritional component involved in the success of this training method. A strict diet is necessary for optimal desired effects.[18]

Power lifting is an oxymoron in that the exercises included are not power exercises. Bench, squat and deadlift are the three exercises performed in power lifting and are all non-ballistic style lifts where are power lifts are actually ballistic in nature. This terminology was introduced before the science behind the action had time to catch up, and therefore it is stuck as a misnomer.[18]

Olympic lifting is true power lifting; this style encompasses the power clean, the jerk press and the snatch lift. All three of these exercises are performed with incredible speed, accuracy and power production.[18]

Program Design

There are two main branches of program design; the goal and the structure. There are four main goals to choose from when designing a resistance training program; Strength, Hypertrophy, Endurance, and Power. The training intensity, repetition range and rest time is manipulated within each goal to individualize the desired outcome for that goal. Strength's intensity is heavy, meaning the load will be greater than or equal to the 85% of the individuals 1 repetition maximum (1RM). The repetition range for strength is low, between 1-6 reps. Rest period is high for strength ranging from 2-5 minutes. Hypertrophy uses a moderate intensity of 67-85% of 1RM. Moderate repetitions are used ranging from 6-12 reps. The rest period is also moderate and is between 30 seconds and two minutes. Endurance intensity is light, using less than or equal to 67% of 1RM. The repetitions associated are greater than or equal to 12 reps; the rest is low and only ranges from 30-60 seconds. Power uses intensity from moderate to heavy with a 75-90% load of 1RM. The reps stay low with power, 1-5 reps. The rest period is high, from 2-5 minutes.[2]

The second branch of program design is structure of the resistance training. Periodization is an important concept to incorporate into any resistance training program; it is the programmed variation in the acute program variables. Periodization is the greatest tool in for the improvement of performance. A resistance training program void of periodization runs a high risk of developing overtraining syndrome.[2, 16, 26, 27] The acute program variables include choice of exercise, order of exercise, sets/reps, load and rest period. Choice of exercise is dictated by the muscle group you want to stimulate. The order of exercise is important when incorporating large muscle groups with smaller ones. Multi-joint exercises should be done before single-joint exercises or large muscle groups before smaller ones. Sets/reps are determined by the volume of work that your desired outcome requires. Load refers to the weight of resistance used when performing an exercise. The load can be a percentage of 1RM or an absolute number. The last acute program variable is rest period. Rest periods coincide with the outcome goal chosen.

Supersetting is a method used to either shorten a workout or increase strength gains. Supersetting is performing two exercises that are agonist of each other or stimulate opposite extremities while keeping to one rest period for both.[2, 16, 26, 27]

Resistance Training Injury

Calhoon et al studied elite competitive Olympic weightlifters and found that because of the anatomical structure of the shoulder; flexing it into an extreme overhead position much like the "catch" portion of snatch, increases the risk of injury. [17] Quatman et al studied high school to college aged athletes and their resistance training injuries. Men observed higher injury rates of the exertion type, such as sprains and strains, specifically in the trunk. Women observed greater risk of injury in resistance training for accidental and lower body extremity. Accidental injury included dropping of the weight, tripping over equipment, or the improper use of equipment. A prevention strategy for men was to increase supervision of technique, and improve appropriate resistance intensity selection. For women, an emphasis on safe equipment use, proper lifting technique, strict safety guidelines, and appropriate supervision was proposed. [20] Reynolds et al found women to have an injury rate of 2.8 injuries per 1,000 exposure hours in a resistance training and running protocol. [21]

Resistance Training Injury Type

Acute injuries are those which occur with rapid onset, secondary to traumatic event. There are two types of acute injury, emergent and non-emergent. Emergent injuries result in greater than five days of lost activity. Within emergent injuries there are two sub categories, musculoskeletal and non-musculoskeletal. Musculoskeletal include fractures, dislocations, and tendon rupture. Non-musculoskeletal injuries include subarachnoid hemorrhage, spontaneous pneumothorax, hernia, myocardial infarction, stroke, and epitaxis. Non-emergent injuries result in less than five days of lost activity and include muscular strains, and ligament sprains.[18]

Chronic resistance training injuries are the result of repetitive stress being placed on tissue that has insufficient time or recuperative ability to heal. Budgett et al defined overtraining as a prolonged fatigue and underperformance, following a period of heavy training or competition lasting at least two weeks and confirmed on an appropriate ergometer or by comparing training rimes or results in previous competition. [16] Reynolds et al observed 79% of injuries sustained were of the overuse nature. [21] Overuse injuries include tendinopathy, arthritis, and stress fractures. Lavallee et al found knee and shoulder injuries were the most common in tendinopathies, due to the deep loaded knee flexion required in clean, snatch and squat.[18] Lavallee et al attributed arthritic injury to years of repeated training stress placed on major joints.[18] Lavallee et al observed that the majority of stress fractures in resistance training occur at sites of repetitive load.[18]

Velocity related injuries included ballistic and non-ballistic exercises. Olympic lifting is of a ballistic nature; Lavallee et al concluded that the load is being accelerated very quickly while generating great amount of power and force. Dislocations, tendon ruptures and fractures are the types of injuries typically seen in Olympic exercises. Great stress on active stabilization and control by smaller supporting muscles, resulting in strains and rotator cuff injuries. The shoulder is most at risk body part due to the extreme flexion and abduction necessary.[18] Non-ballistic injuries include body building or power lifting. Lavallee et al found these injuries due to significant and extreme stress placed on particular joints or structures, such as the acromioclavicular and sternoclavicular joints causing clavicular osteolysis.[18]

Age related injuries in resistance training include youth and elderly. Adirim et al found that over one third of youth athletes will sustain an injury that will require medical attention. Findings observed contusions and strains to be the most common injury in youth. Risk factors for injury of youth in sport included: children have larger surface area to mass ratio, children have bigger heads proportionately, children may be too small for protective equipment, growing cartilage may be more vulnerable to stresses, and children may not have the complex motor skills needed for certain sports until after puberty. [15] 2. Myer et al found that youth sustained more accidental resistance training injuries, especially fractures than did the compared adult population. Youth resistance training should focus on the safe use of equipment to avoid accidental injury, proper resistance training techniques, appropriate intensity progression to develop strength and power. [19] Lavallee et al concluded that injuries to youth related to risk of growth plate or growth velocity injury and risk of accident or lack of supervision injuries.[18] Lavallee et al found that degenerative joint disease was common among the elderly resistance training individuals and that tendinopathies and tendon ruptures occur between 65-70 years of age. After 70, the rate of decline in muscular strength exceeds the rate of decline in the tendon strength.[18]

Hypothesis

1. Based on previous studies, we believe that women will have a higher injury rate than men in resistance training.

2. We expect to see Strength training have a higher injury rate than Hypertrophy and Endurance training based on limited previous studies as well as the anecdotal belief that injuries arise from heavy loads.

Chapter 3

Methods

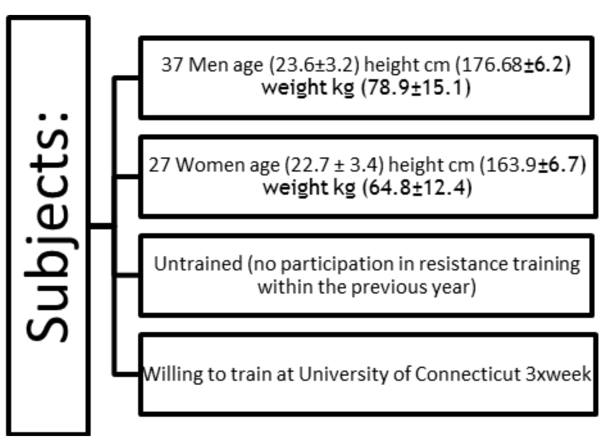
Experimental Approach to the Problem

In this study we examined 64 untrained men and women ranging from 18-35 years of age to participate in a 32 week periodized resistance training program. Subject trained 3 times a week for 8 months for a total of 96 workouts. The workouts consisted of approximately 1 hour in duration and at every training session there were certified trainers present.

Subjects

There were 64 subject, 37 of them were men of the average age of 23.6 years and standard deviation of 3.2; average height was 176.68 cm with a standard deviation of 6.2; and an average weight of 78.9 kg with a standard deviation of 15.1. 27 were women with an average age of 22.7 and a standard deviation of 3.4; average height of 163.9 cm and a standard deviation of 6.7; average weight of 64.8 kg with a standard deviation of 12.4.

Table 3.1



Subjects were untrained, meaning that they couldn't have been involved in resistance training within the previous year. Subjects were excluded if they had a body weight of over 320 pounds, had a blood pressure that was above 150 systolic over 95 diastolic, had diabetes, used tobacco products, took cholesterol lowering medication or blood pressure lowering medication, if they had lost or gained 7 pounds in the last 3 months, taking anti-inflammatory medication, consumed alcohol more than 3 drinks per day or 18 drinks per week, were pregnant, had abnormal menstrual cycle, or had an allergy to whey or soy protein. Subjects had to be willing to attend resistance training sessions 3 times a week at the University of Connecticut. This study was approved by the University of Connecticut: Institutional Review Board for use of human subjects who signed a written informed consent document after the risks and benefits were explained to them. (See Appendix A)

Procedures

Each subject scheduled a time with their assigned personal trainer to attend a session at least 3 times per week. The personal trainers were all NSCA certified strength and conditioning specialist. Each training session was approximately 1 hour in duration; so for the purpose of this study 1 workout equaled 1 exposure hour. There were 96 total workouts, therefore 96 exposure hours per subject; resulting in a study total of 6,144 total exposure hours. Each subject was given a workout log binder that contained all 96 of their organized pre-planned workouts. Workouts were consistent across subject, everyone started on the same day one workout and everyone ended on the same day 96 workout. The workouts were alternated between intensities of heavy, moderate and light. A flexible nonlinear program was used in reference to the Optimizing Strength Training book by Fleck and Kraemer. [27] It allowed for a planned 12 week mesocycle that incorporated flexible days of training to optimize each workout (*eg*, if a participant felt fatigued on a scheduled heavy loading day, a lighter load could be used and the heavy day made up later in the weekly training cycle). This program feature was essential for the success of a long term training program. A further benefit was the planned low intensity periods, which allowed for positive adaptations to occur. Participants were given planned low intensity recovery workouts during the natural breaks in the academic schedule (*eg*, Thanksgiving, Spring Break). Training continued over Winter break with rest phases planned for that period of time within the periodized scheduling.

Table 3.2

Intensity	Goal	Repetitions	Rest
Heavy	Strength	Low, 3-6	High, 180 sec
Moderate	Hypertrophy	Medium, 7-10	Medium, 120 sec
Light	Endurance	High, >11	Low, 60 sec

A training session would begin with a standardized warm up. The warm-up included 10 body weight squats, 10 alternating walking lunges, 10 alternating lateral lunges, 10 alternating knee hugs, 10 alternating quad pulls, and finish up with 10 alternating toy soldiers (kick-outs). Once the subject completed the warm-up they organized their exercises and determined what load would be used by looking back to the previous similar workout with the same exercise and use that number as a starting weight. If the subject wanted to superset their workout, they would pair the necessary exercises at that time. Bench, squat or deadlift were not supersetted with anything and they had to perform these exercises prior to others for optimal strength gains as well as safety.[2, 25-

27] After each set was completed, a timer was started to monitor rest period and the number of repetitions completed were documented in the log book. At the end of the workout the trainer would check to make sure the log book was filled out along with making any comments pertaining to injury. If the subject expressed no complaints, they would initial the workout and that would conclude a training session.

The injury definition used was any complaint of perceived pain in which the subject adjusted the load or set/reps, ceased the exercise, or discontinued the training session.

Figure 3.1

	DATE			
Day 1	Week X	3-5 reps	180 s. rest	Notes:
	set 1	set 2	set 3	
Walking DB Lunge				
Seated row				
Incline bench				Subject Reports No Complaints Upon Exit:
RDLs				(Subj Initial/Date): _________
DB Shoulder press				
MB Push Press Throw				
Push-ups (Max Reps)				Trainer Initial/Date (Supplement): _________

	DATE			
Day 2	Week X	8-10 reps	180 s. rest	Notes:
	set 1	set 2	set 3	
Squat				
Close-grip bench				
Pulldown				Subject Reports No Complaints Upon Exit:
Plate raise				(Subj Initial/Date): _________
Bicep curl				
Pushups (Max Reps)				
DB Step Ups				Trainer Initial/Date (Supplement): _________

	DATE			
Day 3	Week X	10 reps	120 s. rest	Notes:
	set 1	set 2	set 3	
In-Place DB lunge				
Bench				Subject Reports No Complaints Upon Exit:
Pulldown				(Subj Initial/Date): _________
Push press				
Upright row				
Pushups (Max Reps)				Trainer Initial/Date (Supplement): _________

Statistical Analysis

Injury rates were calculated per exposure hour by dividing the total injuries by the multiple of exposures and total exposure hours. All injury rates were adjusted for injuries per 1,000 exposure hours. The data was analyzed using Chi-square method for comparing observed and expected data. If Chi-square was found to be statistically significant, then a Cramer's V analysis was performed to find the measure of association between the variable. **Equation 3.1**

$$\chi^2 = \sum \frac{(observed - expected)^2}{expected}$$

Degrees of Freedom were determined by multiplying the columns-1 and the rows-1. The critical value for a 95% confidence interval was 3.841.

Equation 3.2

$$V = \sqrt{\frac{X^2}{(sample\ size)}}$$

Table 3.3

V	Association
0 - 0.1	Little if any association
0.1 - 0.3	Low association
0.3 - 0.5	Moderate association
>0.5	High association

Chapter 4

Results

Injury Rates Overall

There were 64 subjects who completed the 9 month study, 6144 exposure hours & 66 injuries = 10.74 injuries per 1,000 hours. The primary findings of this investigation observed a significantly higher injury rate in men that women (χ^2=7.492, V=0.3 low). **Figure 4.1** illustrates the injury rates per 1,000 exposure hours among men and women.

Type	Exposures	Injuries	Exposure Hours	Rate	Rate/1,000 Exposure Hours
Men	37	48	3552	0.0135	13.51
Women	27	18	2592	0.0069	6.94
Total	64	66	6144	0.0107	10.74

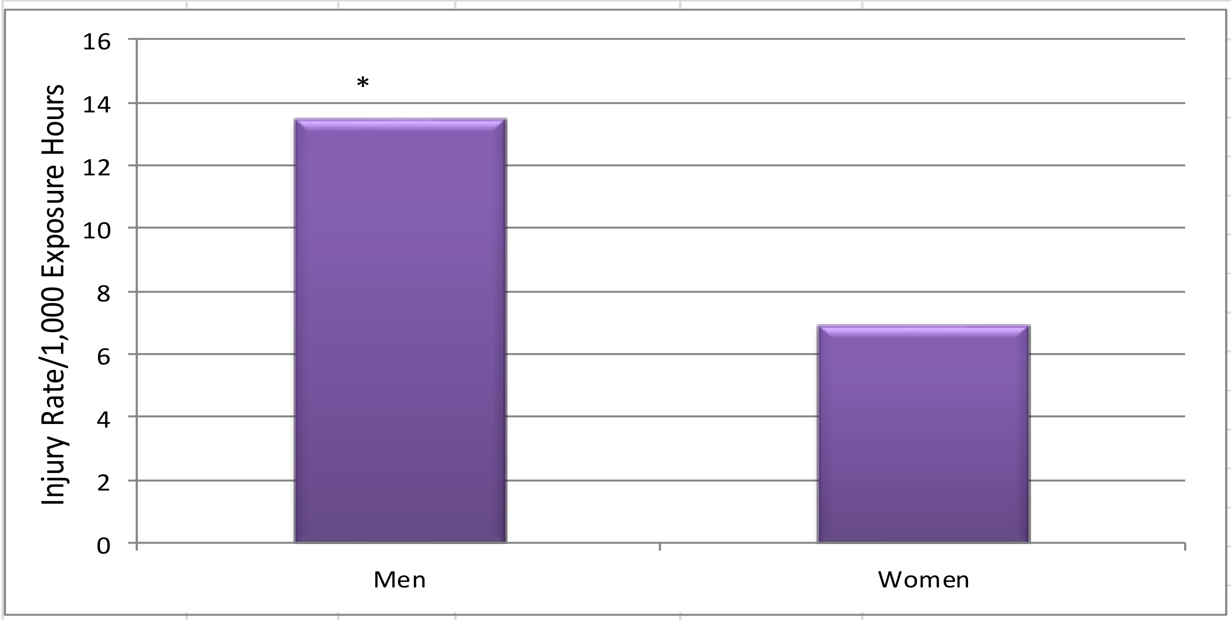


Figure 4.1

Significant gender differences were observed from month 1-4 to month 5-8. There was a significant difference between injury rates in men for month 1-4 and injury rates in men for month 5-8 (χ^2=6.75, V=0.3 mod). There was a significant difference between men and women for month 1-4(χ^2=7.97, V=0.4 mod). There were no significant differences in women from month 1-4 to month 5-8 or between men and women in month 5-8. **Figure 4.2** Illustrates the injury rates per 1,000 exposure hours for men and women across month 1-4 and month 5-8.

Month 1-4	Exposures	Injuries	Exposure Hours	Rate	Rate/1,000 Exposure Hour
Men	37	33	1776	0.0186	18.58108108
Women	27	10	1296	0.0077	7.716049383
Month 5-8					
Men	37	15	1776	0.0084	8.445945946
Women	27	8	1296	0.0062	6.172839506

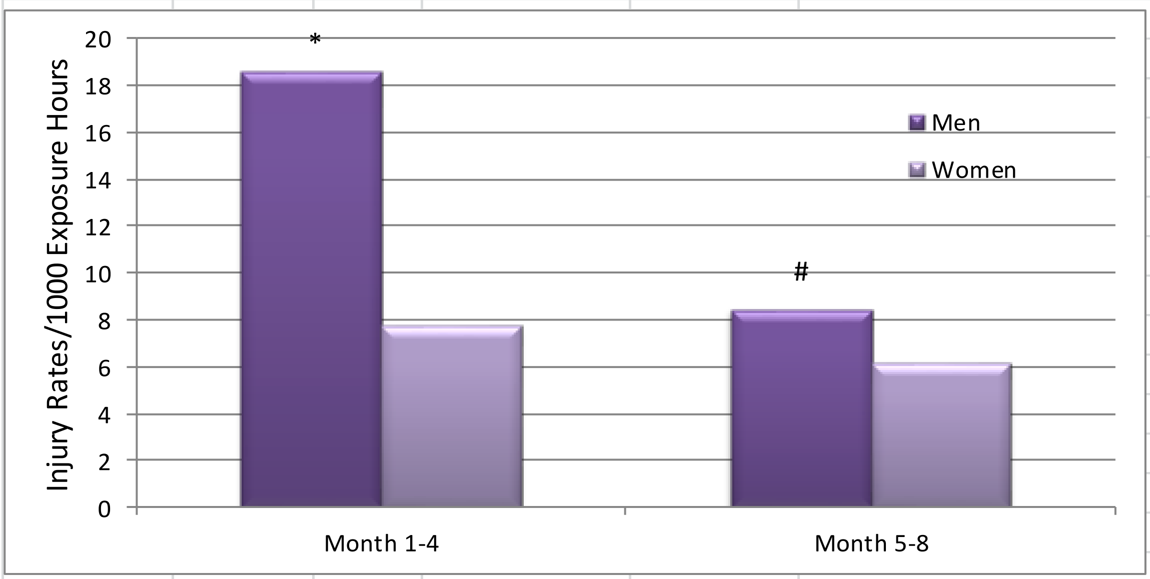


Figure 4.2

There were significant differences in the injury rate of Strength workouts versus Hypertrophy and Endurance workouts (χ^2=7.98, V=0.4mod). Strength had significantly lower injury rates than Hypertrophy (χ^2=5.387, V=0.3 low) Strength had significantly lower injury rates than Endurance (χ^2=7.5, V=0.3 low). **Figure 4.3** illustrates the injury rates per 1,000 exposure hours among Strength, Hypertrophy and Endurance.

Type	Exposures	Injuries	Exposure Hours	Rate	Rate per Exposure Hour
Strength	24	10	1536	0.0065	6.510416667
Hypertrophy	54	41	3456	0.0119	11.86342593
Endurance	18	15	1152	0.0130	13.02083333
Total	96	66	6144	0.0107	10.7421875

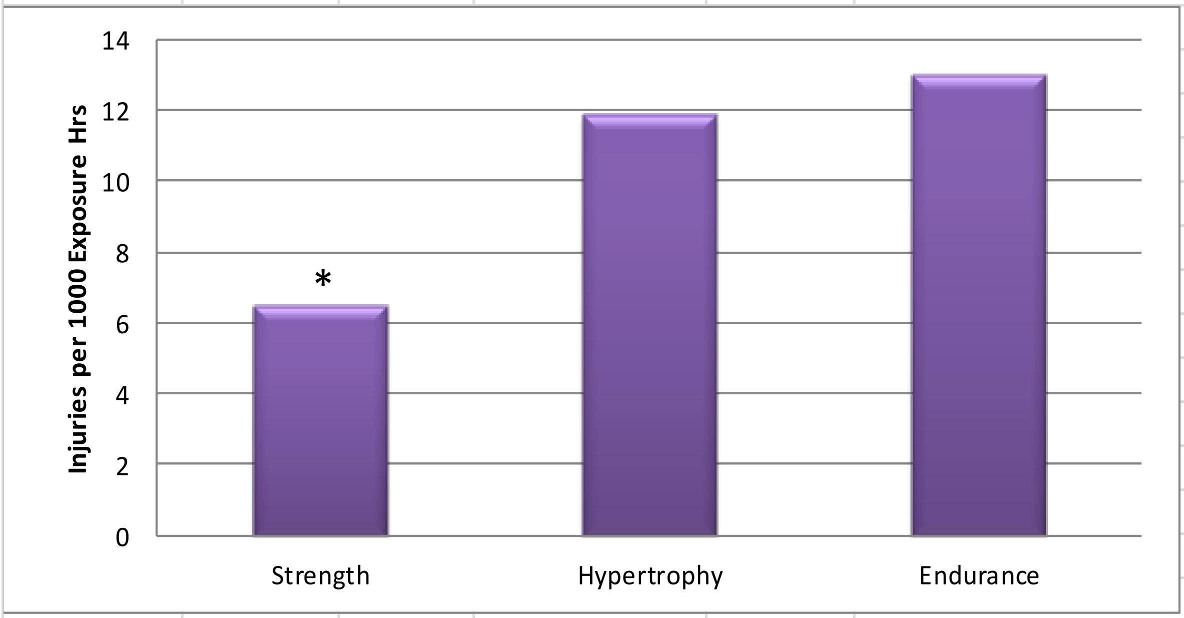


Figure 4.3

Significant differences were observed when comparing Strength, Hypertrophy and Endurance in month 1-4 (χ^2=25.07, V=0.6 high). There was a significant difference between Strength and Hypertrophy in month 1-4 (χ^2=11.28, V=0.4 mod). There was a significant difference between Strength and Endurance in month 1-4 (χ^2=25.6, V=0.6 high). There was no significant difference in Hypertrophy and Endurance in month 1-4. There were no significant differences among Strength, Hypertrophy, or Endurance in month 5-8. There was a significant difference in Hypertrophy from month 1-4 to month 5-8 (χ^2=5.94, V=0.3 low). There was a significant difference in Endurance from month 1-4 to month 5-8 (χ^2=16, V=0.5 high). There was no significant difference in Strength from month 1-4 to month 5-8. **Figure 4.4** Illustrates injury rates per 1,000 exposure hours of Strength, Hypertrophy, and Endurance across month 1-4 and month 5-8.

Month 1-4	Exposures	Injuries	Exposure Hours	Rate	Rate/1,000 Exposure Hour
Strength	10	3	640	0.0047	4.6875
Hypertrophy	32	31	2048	0.0151	15.13671875
Endurance	6	9	384	0.0234	23.4375
Month 5-8					
Strength	14	7	896	0.0078	7.8125
Hypertrophy	22	10	1408	0.0071	7.102272727
Endurance	12	6	768	0.0078	7.8125

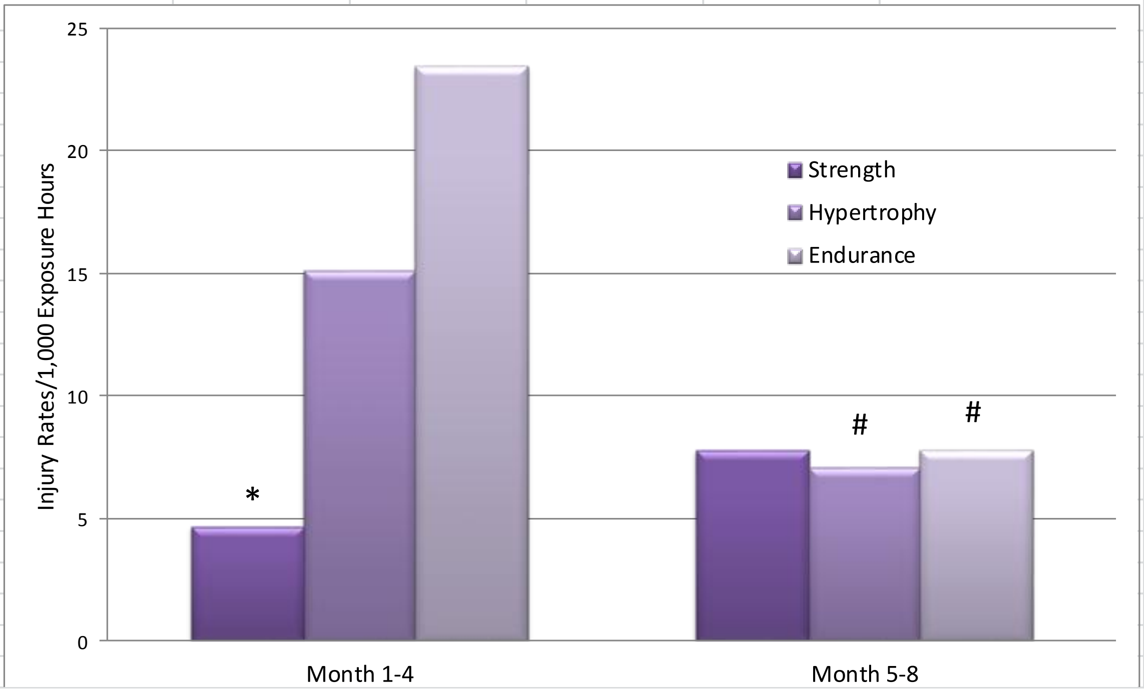


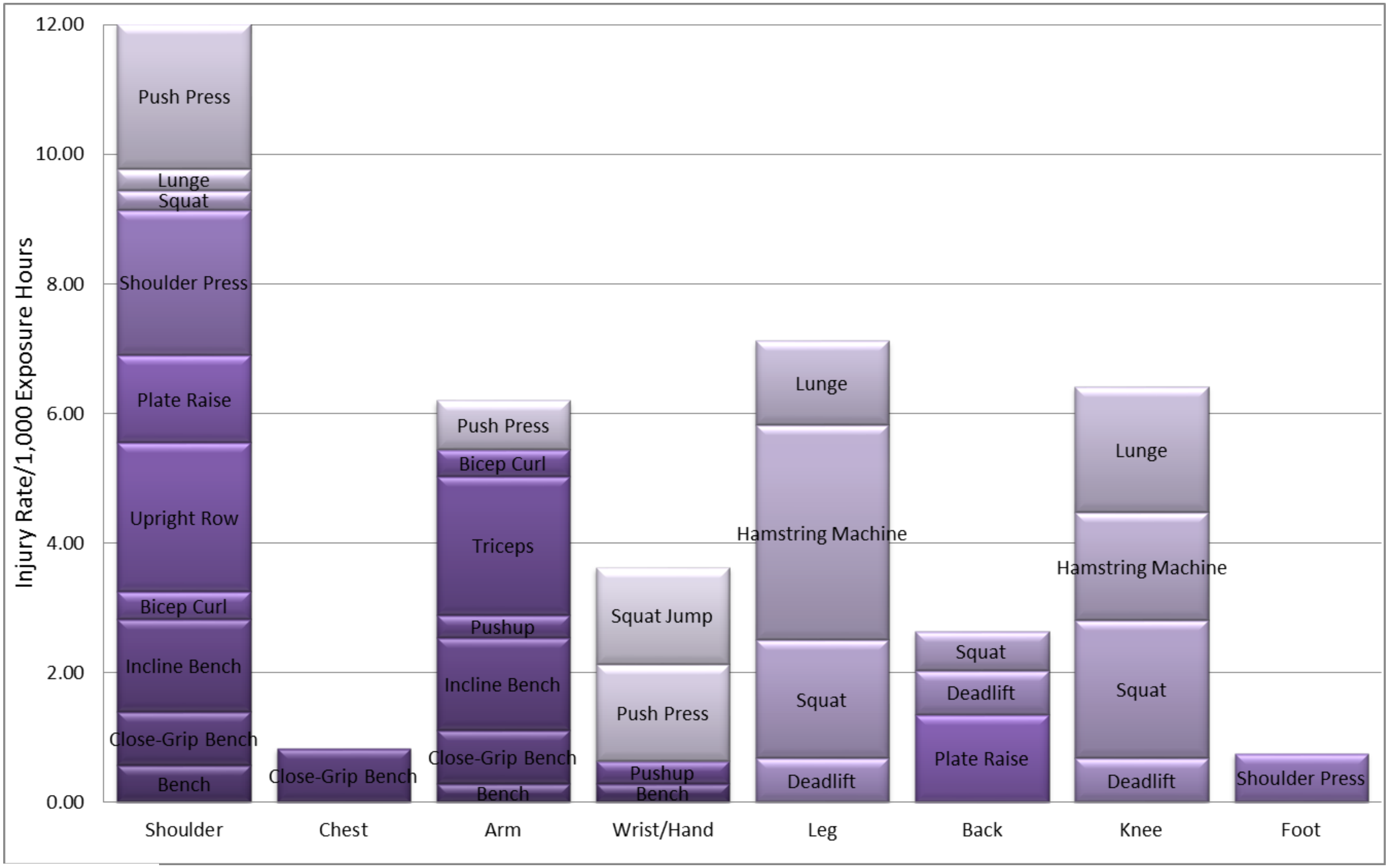
Figure 4.4

Table 4.1 Describes the injury rate for body part injured (horizontal axis) and the exercise in which the injury occurred (vertical axis). The rates are per 1,000 exposure hours to an exercise. The highest rate of injury to a specific body part per 1,000 exposures was the Hamstring Machine (4.98 Leg injuries per 1,000 exposure hours). The second highest rate of injury for a specific body part was the squat with (4.87 injuries per 1,000 exposure hours). The third highest injury rate was the push press with (4.48 injuries per 1,000 exposure hours) "EXP" refers to the total exposures for all subjects to that exercise throughout the investigation.

Table 4.1

Chest Emphasis	Rate/1000 Exposures	Exposure Hours	Knee	Shoulder	Arm	Wrist/Hand	Chest	Leg	Back	Foot
Bench	0.86	3484		0.57	0.29	0.29				
Close-Grip Bench	2.49	1206		0.83	0.83		0.83			
Incline Bench	2.84	1407		1.42	1.42					
Pushup	0.71	2814			0.36	0.36				
Upper Body	**Rate/1000 Exposures**	**Exposure Hours**	**Knee**	**Shoulder**	**Arm**	**Wrist/Hand**	**Chest**	**Leg**	**Back**	**Foot**
Row	0.00	2345								
Pulldown	0.00	2479								
Pull-up/Inverted Row	0.00	536								
Triceps	2.13	469			2.13					
Bicep Curl	0.85	2345		0.43	0.43					
Ab	0.00	2412								
Shoulder	**Rate/1000 Exposures**	**Exposure Hours**	**Knee**	**Shoulder**	**Arm**	**Wrist/Hand**	**Chest**	**Leg**	**Back**	**Foot**
Front Raise	0.00	201								
Upright Row	2.30	1742		2.30						
Plate Raise	2.71	737		1.36					1.36	
Shoulder Press or Seated Press	2.99	1340		2.24						0.75
Leg Emphasis	**Rate/1000 Exposures**	**Exposure Hours**	**Knee**	**Shoulder**	**Arm**	**Wrist/Hand**	**Chest**	**Leg**	**Back**	**Foot**
Deadlift	2.04	1474	0.68					0.68	0.68	
Squat	4.87	3283	2.13	0.30				1.83	0.61	
Lower Body	**Rate/1000 Exposures**	**Exposure Hours**	**Knee**	**Shoulder**	**Arm**	**Wrist/Hand**	**Chest**	**Leg**	**Back**	**Foot**
Romanian Deadlift	0.00	1005								
Hamstring Machine	4.98	603	1.66					3.32		
Lunge	3.57	3082	1.95	0.32				1.30		
Calf	0.00	1206								
Power	**Rate/1000 Exposures**	**Exposure Hours**	**Knee**	**Shoulder**	**Arm**	**Wrist/Hand**	**Chest**	**Leg**	**Back**	**Foot**
Push Press	4.48	1340		2.24	0.75	1.49				
Push Press Throw	0.00	201								
Squat Jump	1.49	670				1.49				
High Pull	0.00	737								
Chest Pass	0.00	402								

Figure 4.5 Illustrates the injury rate per 1,000 exposure hours of the exercise performed and its contribution to the total injury rate of body parts injured. The shoulder had the highest injury rate with (12.01 injuries per 1,000 exposure hours). The leg was second highest at (7.13 injuries per 1,000 exposure hours). The third highest injury rate was the knee with (6.42 injuries per 1,000 exposure hours). The fourth highest injury rate was in the arm with (6.21 injuries per 1,000 exposure hours).



Injury Rate/1,000 Exposure Hours
12.00
10.00
8.00
6.00
4.00
2.00
0.00
Push Press
Lunge
Squat
Shoulder Press
Plate Raise
Upright Row
Bicep Curl
Incline Bench
Close-Grip Bench
Bench
Close-Grip Bench
Push Press
Bicep Curl
Triceps
Pushup
Incline Bench
Close-Grip Bench
Bench
Squat Jump
Push Press
Pushup
Bench
Lunge
Hamstring Machine
Squat
Deadlift
Squat
Deadlift
Plate Raise
Lunge
Hamstring Machine
Squat
Deadlift
Shoulder Press
Shoulder
Chest
Arm
Wrist/Hand
Leg
Back
Knee
Foot

Figure 4.5

Chapter 5

Discussion

Hypotheses

Contrary to previous studies, we found the injury rate in men to be significantly higher than the injury rate found in women. No scientific measurements show in certainty the rationale for men having a higher injury rate than women. Future research might look into the psychological paradigm involving men and women in sport to draw conclusions. [31] Men may feel more comfortable within the resistance training realm due to women being a fairly new addition to the resistance training world. Perhaps men on average push heavier weight per percentage body weight and they feel comfortable to push themselves harder than women, both which could account for their higher injury rates.

Our research found that both hypertrophy and endurance training had significantly higher injury rates than did strength training; an important note to the anecdotal notion that training heavy loads will cause injury. Brandenburg et al found with a decreased load protocol, fatigue increased through measurements of maximal isometric force and lactate levels when compared to a constant and on average heavier load. [32] Vetter et al observed in a review of NCAA athletes that training intensity fatigue was related to acute and chronic injury. [33] Brandenburg's data suggest that a hypertrophy or endurance style workout could potentially elicit a greater degree of fatigue than would a strength style workout due to the total work involved in each. If a higher fatigue level is related to injury than it may explain why we saw higher injury rates in hypertrophy and endurance workouts.

Reynolds et al found in a similar study done only in women that the majority of injuries occurred at week 12 of a 24 week resistance training program. Week 12 was when the training load was approaching its peak, however the training load peaked again around week 22 and the same rise in jury was not seen. The study attributed conditioning status changes as the reason for fewer injuries in the second peak load. The women's conditioning status was much lower at the first peak load, increasing their vulnerability to injury.[21] The Reynolds concept can be applied to the current study; in that the increased injury rate in the beginning of the study may be attributable to the conditioning status of the subjects who were untrained.

Future Research

Future Research should focus on development of consistent verbiage. Goldberg et al declared that injury rates should strive to report per 1,000 exposure hours as it is the most specific and universal among different sports. A global injury definition should be constructed to have set inclusion criteria. A measure of severity is necessary, using time lost may overestimate injury rate or underestimate serious injury. Deviations can then exist below the general definition to include duration of injury or re-occurrence of injury etc. [34]

There has been wide spread data collection on injury rates in sport for practice and competition [35], but future research should include injury rates in resistance training practice and competition such as 1RM testing or weightlifting competition.

Practical Applications

We observed that injuries occurred in men in the first four months of the resistance training, predominantly in the hypertrophy and endurance workouts. As a result, an extra emphasis may be warranted on men in the beginning of a program as well as adjusting the program in the beginning to focus on strength with low risk exercises rather than hypertrophy or endurance.

Appendix A

Consent Form for Participation in a Research Project

University of Connecticut

Principal Investigator: Jeff S. Volek and William J. Kraemer

Study Title: The effects of supplementation on responses to resistance exercise

Invitation to Participate

You are invited to participate in this study designed to examine the effects of dietary supplementation with protein versus carbohydrate on responses to resistance training. Resistance training is well known to result in increases in muscle size and strength, but the effects on other health related markers are not as well studied. This project will examine how diet and supplementation with protein and carbohydrate alter responses to 9 months of resistance training in healthy men and women.

Description of Procedures

This research study will take place at the University of Connecticut (UConn) in Storrs and will last approximately 9 months. For this study, you will be required to follow a specific diet and supplementation program and perform resistance training in our facility three times per week for a nine month period. This is specifically what will happen during the research study:

Screening Visit: You will initially be screened, which will include assessment of your medical, nutrition, dietary supplementation, menstrual, and exercise history. We will also determine your height, weight and blood pressure. This visit will take about 30 minutes. We are looking for men and women between 18 and 35 years of age who have not been regularly participating in a high intensity resistance training program. You will be excluded if any of the conditions below are true:

Exclusion Criteria:
1) You have partipated in a resistance training program within the last year.
2) Your body weight is more than 320 pounds.
3) Your blood pressure is more than 150/95.
4) You have diabetes.
5) You regularly use tobacco products.
6) You take cholesterol lowering or blood pressure medications.
7) Your have lost or gained more than 7 pounds in the last 3 months.
8) You are taking anti-inflammatory medication (aspirin, NSAIDs).

9) You consume alcohol more than 3 drinks/day or 18/week.
10) You are pregnant or intend to become pregnant during the 9 mo study period.
11) You have an abnormal menstrual phase.
12) You have an allergy to whey or soy protein.

If you qualify based on the screening visit, we will schedule you for testing. There are a series of tests we will conduct before you start the diet and training portion of the study in order to determine your baseline fitness level. These tests are listed below followed by a brief description of the procedures we will use. We should be able to complete all these tests in three separate visits, but we may need to schedule additional visits depending on your availability.

Testing Measures:
All these tests will be done at baseline and 9 mo of diet and training. In addition, some test will be performed at 3 and 6 months as indicated below. Thus, you will be tested on four separate occasions. We will be asking you to fast for about 12 hours overnight before coming to the laboratory for testing. This means no food or drink that contains calories (including coffee) but you should drink plenty of water. We want you to be well hydrated during all tests. You must also avoid alcohol and strenuous exercise for at least 36 hours prior to coming to the laboratory for testing.

Body weight will be measured on a digital scale.

Body composition (fat, lean, and bone weight) will be determined at four times (baseline, 3, 6, and 9 months) using a machine that will expose you to a small amount of X-ray radiation. You will lie quietly on a table while a scanning arm passes over your body from head to toe. You must remain still for about 5 min during this test. A certified X-ray technician will perform the scan. We will also measure the amount of water in your body by placing two electrodes on your arm and leg while you are comfortably lying down. These tests will take about 1 hour.

Muscle shape will be determined with an ultrasound machine at four times (baseline, 3, 6, and 9 months). We will place a small probe on your upper leg in order to capture various images of the underlying muscle and fat tissues. This test will take about 30 minutes.

Resting Blood pressure will be measured at four times (baseline, 3, 6, and 9 months) by putting a cuff around your arm while you are comfortably seated. Resting blood pressure will take about 15 minutes. We will also attach a monitor that you will wear for an entire day during which time blood pressure and heart rate will be electronically recorded. This will give us an indication of your average blood pressure during the day.

Physical performance will be measured at four times (baseline, 3, 6, and 9 months) by having you lift the most weight in a bench press and squat exercise. Following a standardized warm-up, you will be given multiple attempts to lift as much weight as possible in good form on a specialized machine in our laboratory. Using these same movements, we will assess isometric maximal strength. For this test, you will press up against an immovable bar as hard as possible while we measure your force output. Muscle power will be assessed in the same movements (squat and bench press). We will load the bar with 30% of your previously determined maximum and ask you to perform the movement in an explosive manner to generate as much power as possible. We will also assess your power by having you jump as high as possible off a force platform while you keep your hands on your waist. These tests will take about 1 hour.

Metabolic rate will be determined twice (baseline and 9 months) early in the morning after you have been lying down on a table for 30 minutes. A ventilated canopy will be placed over your head so we can collect your expired breath for about 20 minutes. The expired breath that is collected will be analyzed for oxygen and carbon dioxide content so that we can calculate the amount of energy (kcal) you are burning. During the test you will be required to rest quietly and breath normally but you will not be allowed to fall asleep. We will also ask you to collect your urine in a container for a 24-hour period starting on the morning of the visit for resting metabolic rate testing. This test allows us to determine how many calories you burn during the day while at rest. This test will take about 1 hour.

Blood will be taken from a vein in your arm to assess resting levels of several health related markers (lipids, hormones, etc.). The amount will be equal to about ½ cup. Thus, over the four visits at baseline, 3, 6, and 9 months we will collect 2 cups of blood total. We will be freezing a portion of your blood that may be used at a later point in time to analyze for specific genes affecting your response to the diet and exercise training. We will not share the results of the genetic analysis with you because they have no direct benefit to you. The blood draw will take about 20 min.

An ***Acute Resistance Exercise Test*** will be performed twice (baseline, 3, 6, and 9 months) to assess how your body responds to an exercise bout. For this test, we will put a flexible catheter into a vein in your arm so that we can draw blood before exercise, immediately after exercise, and 15, 30, and 60 min post-exercise. The total amount of blood during this test will be a little more than ½ cup. The exercise bout will consist of a warm up followed by 6 sets of 10 maximal repetitions of squat. This test will only be done at baseline and after 9 months of diet and training and will take 90 minutes. Thus, the total blood from these tests will be one cup. The total amount of blood collected during the whole study including the resting blood will be a little more than 3 cups.

<u>Supplementation and Diet Assignment:</u>
After baseline testing, you will also be randomly (like pulling a number out of a hat) placed into one of 3 groups. You may also request to be in a control group that only performs the testing described above but does not participate in the supplementation and resistance training.

1. Carbohydrate Supplementation + Resistance Training
2. Whey Protein Supplementation + Resistance Training
3. Soy Protein Supplementation + Resistance Training

Depending on your group assignment, you will be provided with a 2-week supply of the supplements and instructed to consume one serving per day with breakfast on non-training days and immediately after exercise on training days. Each serving contains about 190 kcal. Since it is critical you take the supplement every day, we will ask you to record the time you consumed the beverage each day on log sheets.

In addition to being randomized to a supplementation group, we will counsel you to follow a diet that is designed to meet your caloric needs and that contains a specific amount of protein that should remain constant over the 9 months. The diet will follow general diet guidelines (55-60% carbohydrates, 15-20% protein, and 25-30% fat) emphasizing restriction of saturated fat (<7%) and cholesterol (<300 mg/day). Counseling will focus on making healthy carbohydrate choices, encouraging whole-grain products, fruit and vegetable intake, and lean protein sources.
In order to help you with the diet and monitor compliance, we will ask you to complete a 5-day food record every month. You will be given a small scale to weigh food and specific instructions on how to complete the food logs. We will also ask you to attend regular nutrition meetings one time every two weeks. One of the meetings will be a group meeting and the other a one-on-one meeting with one of our study nutritionists. During the meetings, we will provide you with specific diet advice to help you follow the appropriate guidelines and enhance motivation. We will give you educational materials and counseling regarding the diet including specific lists of appropriate foods, recipes, and example meal plans to help you with the diet. To help with motivation and nutrient assessment, we will be providing you with a Personalized Digital Assistant (PDA) with Palm operating system that has nutrient analysis and graphing software. You will be asked to record the food you eat during a 5-day period each month of the study using the PDA. We will provide you with specific training to make sure you feel comfortable with the software and operation of the device.

Resistance Exercise Training:
All groups will perform resistance training. Training will occur three times per week. We will have designated times you can come to our facility in the Human Performance Laboratory. All sessions will be supervised by a certified personal trainer (CSCS). The program will include a variety of exercises to stimulate major muscle groups and provide variation. The entire workout will take approximately 1 hour.

Risks and Inconveniences

Supplementation Protocol. You should not be in this study if you have any major medical problems. If you are unsure, discuss your health history with the Principal Investigator. There are very few potential risks associated with the procedures used in this study. You should inform us if you have an allergy to soy or whey protein in case you are selected to be in one of these supplementation groups.

Blood Draws. Blood draws with a needle may cause discomfort at the puncture site and the development of a slight bruise. You may also experience lightheadedness or fainting during the blood draw. There is a slight risk of infection from these procedures. All possible precautions to avoid infection will be taken including use of sterile disposable needles, drapes and gauze and the practice of aseptic techniques during blood sampling. All blood samples will be obtained by trained people. You should refrain from giving blood during the course of the study.

Body Composition. You will be exposed to a very small amount of radiation by the scanner used to measure your body composition. Exposure to any amount of X-ray radiation, no matter how low, may cause abnormal changes in cells. However, the body continuously repairs these changes and the amount of radiation is very low in this study. The total exposure for a whole body scan is approximately 125 times less than the average radiation from a standard chest x-ray. Thus, the radiation levels are extremely low and the health risk minimal. We don't know what effect the radiation could have on an unborn baby so pregnant women should not be in this study. As a precaution we will ask women to take a urine pregnancy test before the scan. For the muscle shape measures, there are no known harmful effects from the use of ultrasound.

Resistance Training and Testing. Even though the resistance exercise program and testing protocols are designed to be safe, there is the risk that you may become injured. The researchers have an extensive experience in conducting short-term and long-term exercise studies, and they will do everything possible to reduce the chance of injury. Every effort will be made to make the study safe by proper supervision of proper technique during testing and exercise sessions. However, if you experience pain, unexpected discomfort, soreness, headache, loss of concentration, dizziness, vomiting, unusual fatigue or difficulty breathing you should immediately inform one of the supervising members of the research team, who will bring this to the attention of the principal investigators and the medical monitor. The performance of resistance exercise can entail a certain degree of risk from overexertion and/or accident. There are minimal risks for muscle strains or pulls of the exercised muscles. In very rare cases you can experience muscle spasms or tears. Some muscle soreness may be experienced 24 to 48 hours after exercise and this should completely subside with a few days and have no long-lasting effects. The risk of heart attack, although very small, does exist. The chance of any of these events occurring will be minimized by our screening, selection and monitoring procedures, and by the use of properly conducted research procedures. All the research team members are currently certified in CPR.

Urine Collection: There are no risks associated with the 24 hour urine collection, but this may be inconvenient for you. We will provide you a container that you will be asked to collect all your urine for entire day. You should keep the container refrigerated during the collection period.

Genetic Testing. It is not the purpose of this study to look for or provide you with any medical information or diagnoses relating to your present condition or any other disease or illness. Thus, we will not share the results of the genetic analysis with you. The risks associated with this study are mainly psychological and social. You might worry about having a possible genetic disorder. Although unlikely, there is a possibility that incidental findings might be made such as your risk for a certain disease. Your gene results could be used against you if some of these genes are ultimately shown to predict future disease. This could lead to discrimination, potential loss or difficulty in obtaining employment or insurance. For this reason, your DNA sample will be identified by a code number, and all other identifying information will be removed. The Principal Investigator will keep a code sheet which links the sample code number with your name locked separately and this will be destroyed after two years. This information will not be disclosed to third parties except with your permission.

Benefits

The results of this study will help to determine the role protein supplementation has on responses to weight training and general health, and therefore contribute to a better understanding of dietary recommendations to enhance health. You will be provided with a facility to train under supervised conditions for 9 months during the study. You will also learn your body composition and will most likely improve your fitness and health status.

Economic Considerations

If you complete all training and testing you will receive a stipend of $400 at the end of the study. The stipend will be prorated if you do not complete the study: $50 after completion of baseline testing, $100 after completion of 3 month testing, and $100 after completion of 6 month testing.

If you are selected for the control group that only performs testing (no training) you will receive $200 for completion of all testing sessions. The stipend will be prorated for those who do not complete the study: $25 after completion of baseline testing, $50 after completion of 3 month testing, and $50 after completion of 6 month testing.

Confidentiality

All the data collected will be kept for a minimum of five years and remain confidential and you will never be identified by name in any reporting of results. Further, the results will not be shared with any person outside the investigation without your consent. The results of this study will be kept in locked cabinets under the supervision of Dr. Volek and Dr. Kraemer. You should also know that the UConn Institutional Review Board (IRB) and the Office of Research Compliance may inspect study records as part of its auditing program, but these reviews will only focus on the researchers and not on your responses or involvement. The IRB is a group of people who review research studies to protect the rights and welfare of research participants.

Confidentiality of your genetic information will be of high priority to protect the DNA samples from falling into unauthorized possession. All blood samples for gene testing will be identified by a code number, and all other identifying information will be removed. The code number will be linked to the physiological data already obtained from you. The genetic information will be kept at a separate facility where the genetic testing will be done. This information will be kept electronically and/or in locked files. The code sheet which links your sample code number with your name will be kept in a locked file and office in a different location at the University of Connecticut. This information will be in hard copy form only and not electronic. The code sheet will be destroyed after two years. Your genetic information will not be disclosed to third parties except with your permission.

In Case of Illness or Injury

In the event you become sick or injured during the course of the research study, immediately notify the principal investigator or a member of the research team. If you require medical care for such sickness or injury, your care will be billed to you or to your insurance company in the same manner as your other medical needs are addressed.

If, however, you believe that your illness or injury directly resulted from the research procedures of this study, you may be eligible to file a claim with the State of Connecticut Office of Claims Commissioner. For a description of this process, contact the Office of Research Compliance at the University of Connecticut at 860-486-8802.

Voluntary Participation

You do not have to be in this study if you do not want to. If you agree to be in the study, but later change your mind, you may drop out at any time. There are no penalties or consequences of any kind if you decide that you do not want to participate.

Do You Have Any Questions?

Take as long as you like before you make a decision. We will be happy to answer any question you have about this study. If you have further questions about this project or if you have a research-related problem, you may contact the principal investigator, Jeff S. Volek at 860-486-6712. If you have any questions concerning your rights as a research subject, you may contact the University of Connecticut Institutional Review Board (IRB) at 860-486-8802.

Authorization:

I have read this form and decided that ________________________________ will
(name of subject)
participate in the project described above. Its general purposes, the particulars of involvement and possible hazards and inconveniences have been explained to my satisfaction. My signature also indicates that I have received a copy of this consent form.

____________________ ____________________ __________
Participant Signature: Print Name: Date:

Relationship (only if not participant):______________________________

- I agree that my blood sample may be used for gene testing in this study:
  Initials of participant: _____ YES or _____ NO

- I agree that my blood sample and gene data may be used for unspecified future studies:
  Initials of participant: _____ YES or _____ NO

____________________	____________________	__________
Signature of Person Obtaining Consent	Print Name:	Date:

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